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THE NEW RISING SUN: JAPAN'S OPTOELECTRONICS INDUSTRY

Summary

The optoelectronics industry has taken firm root in Japan and is rapidly extending branches into other sectors of the economy. Drawing on a deep pool of human and financial resources from its parent electronics and optical industries and nurtured by careful government attention, this hybrid scion promises to have a major impact on the country's economic structure and global competitive position. Despite a shift of momentum from the public to the private sector, the U.S. and Japanese governments have crossed swords before over this issue and are likely to do so again, perhaps with increasing frequency. This report examines the development of Japan's newest star and reviews the issues separating the two governments.

Optoelectronics: A Broad Spectrum Industry

Optoelectronics combines elements of the optical and electronics industries, yielding a discipline with broader applications and new capabilities. Although it is one of Japan's youngest industries, rapid growth has put its sales on a par with some established high technology sectors including space and nuclear power. Even if private growth forecasts prove optimistic, the industry should become a major factor in the economy by the turn of the century.

Optoelectronic applications fall roughly into five areas: telecommunications, instrumentation, manufacturing, information processing and energy.

Telecommunications - This is one of the largest markets for optoelectronics. Based on laser transmitters and light-conducting cables, fiber-optic communications systems possess numerous desirable characteristics: very high per-cable transmission capacity; low signal attenuation; high resistance to electromagnetic interference; good stability under a range of environmental conditions; and low power consumption. High cost is currently the major disadvantage of these systems, although this drawback should vanish by the beginning of the next decade. Companies are working on fiber-optic systems not only for communications but also for use in factories and offices and in airplanes and motor vehicles. The information and computer explosions that are rocking Japan provide a very fertile field for the development and introduction of optoelectronic communications systems.

Instrumentation - As industrial and medical technology advances, the demand for precision instruments grows. Not only is higher resolution required of measurement apparatus, but real-time speeds are also becoming increasingly important. The ability to measure the temperature of molten metal in a furnace accurately and instantaneously has made possible commercial production of new alloys and materials. In addition, laser holography, by generating three-dimensional images of objects to reveal surface and internal stress patterns, is playing a major role in new materials and structural engineering. Laser gyroscopes, which are as sensitive as mechanical ones, have the additional advantage of requiring no moving parts. The trend toward automated factories relies heavily on optoelectronics, not only for high capacity data transmission systems but also for robotic vision and fault detection/quality control systems. Medical applications are on the rise as detection thresholds descend to the parts-per-billion level, laser microsurgery techniques mature, and fiber-optic diagnostic equipment becomes more versatile.

Manufacturing - The new technology has direct manufacturing applications that promise improved productivity. Industrial lasers presently form the backbone of the optoelectronic manufacturing force, but other optical devices are gaining in use, especially in the microelectronics industry. The power, speed and precision of laser cutting tools is put to use in industries ranging from textiles to aerospace. Beside reducing actual cutting time, production can be accelerated since the laser tool produces near-finished components. In addition, less material is wasted, further reducing costs. Laser tools really shine in their ability to handle the super-strong alloys that are important to so many industries. Their unparalleled cutting and drilling capabilities make materials that are otherwise difficult to handle commercially feasible.

In the microelectronics industry, however, the attraction of optoelectronics is not brute force, but rather precision. Whether it be etching microscopic patterns, depositing super-thin coatings, or implanting minute impurities in silicon wafers, optoelectronic machines provide the only practicable answer.

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This is increasingly true as the industry moves to develop submicron-feature chips, multi-layer chips and wafer-scale chips. Excellence in optoelectronics is a critical component of excellence in integrated circuits and thus computers.

Information Processing - Optoelectronics manufacturers are giving increased attention to this application, both in terms of money and manpower. At this time, the most visible uses are the laser scanners used at checkout counters in retail stores, high-speed photocopiers and printers, and high-definition facsimile machines. The bar code/laser scanner combination not only speeds up long supermarket lines but also moves inventory items more rapidly through the transportation, warehousing and assembly steps of the manufacturing process. Railroads have used bar code readers to track rolling stock for almost two decades, and now other industries, including motor vehicles, are adopting these readers in the drive to reduce inventory costs and modernize production processes. Laser printers and copiers could revolutionize the printing industry. Bookstores, for instance, could keep hundreds of thousands of titles in electronic form and print them out on the spot for a customer. Facsimile technology has advanced to the point where the Japan Patent Office plans to accept patent applications via this equipment.

The real thrust of research in the opto-information field, however, is directed at developing building blocks for an optical computer. The theoretical advantages of optical computers are staggering: computational speeds millions of times faster than even the much-heralded "fifth-generation" computers being developed; information storage capacity measured in the gigabyte or terabyte (billions or trillions of computer words) ranges; and the ability to perform calculations in number bases greater than base-2. (Current computers function in base-2 format, in contrast to humans who generally use base-10.) The practical problems facing researchers, however, are equally impressive: how to create light-based logic elements; how to store and retrieve information in light form; how to coordinate and control optical computer processes; and how to interface the optical computer with the human world. In the opinion of most industry observers, a working optical computer is decades away. Nonetheless, Japanese and American researchers are devoting increasing resources to optical computer projects.

Energy - This aspect of optoelectronics is often left out of discussions of the industry because most countries classify it under alternative energy programs. In Japan, however, the field has been included within the boundaries of optoelectronics as more exotic forms of photovoltaic and laser fusion equipment are developed. Photovoltaics could have broad applications as per-watt costs fall and durability increases. Power arrays using non-silicon based cells will be flown on Japan's upcoming satellites, and solar cells are showing up in a broad range of consumer products. Laser fusion reactors are not likely to be commercially feasible before the end of this century, but the Japanese government is moving ahead with an ambitious development program.

The Dawn of the Optoelectronics Industry: The 1970s

Like many of Japan's high technology industries, the optoelectronics business has its roots across the Pacific in the United States. Lasers and solid-state components were developed by American Telephone & Telegraph Co.'s

(ATT) Bell Laboratories, and U.S. scientists had expounded the basic theories of fiber optics by the early 1960s. Unlike many other knowledge-intensive industries, however, the Japanese have been pioneering shoulder-to-shoulder with the Americans.

Nippon Sheet Glass Co., Ltd and NEC Corp. were the first to succeed in producing a workable fiber-optic cable. This 1969 effort, based on a complicated, jointly developed process, did not offer acceptable performance, however; the strength of the light signal dropped 50 percent every fifteen meters (200 decibels/kilometer). Corning Glass Works took a big step forward the next year when it successfully produced optical fibers with one-tenth the light loss of Japan's first effort. By 1974, Bell scientists had reduced the light-loss factor so that a signal could travel almost 3 kilometers before losing 50 percent of its strength. Three years later, four fiber-optic manufacturing methods had been developed: Bell Laboratory's modified chemical vapor deposition (MCVD) and outside vapor deposition (OVD); N.V. Philips' (Netherlands) plasma chemical vapor deposition (PCVD); and Nippon Telegraph and Telephone Public Corp.'s (NTT) vapor-phase axial deposition (VAD).

MCVD, OVD, and PCVD create optical-fiber preforms (which look like glass sausages) by laboriously layering molten glass containing different amounts of impurities on the inside of glass tubes. NTT's method for making preforms is radically different. Each preform is grown by injecting vaporized glass and other chemicals into a chamber under strict temperature and pressure controls. This method offers significant advantages. The impurity gradient from the center to the outside of each preform, which is responsible for keeping the light beam within the optical fiber without significant loss or interference, is created in a single step. Moreover, it is possible to produce endless preforms that can be drawn into endless optical fibers. This makes continuous production feasible and less time-consuming.

In contrast, development of laser technology has not been one of Japan's strong points, although the Japanese have led the way in applying lasers to industrial and consumer products. In one area, however, they have made significant contributions: semiconductor lasers. Japanese researchers have improved the power and information capacity of solid-state lasers while simultaneously reducing their production costs.

In general, the Japanese have followed the familiar pattern of licensing technology from abroad and targeting scarce financial and human resources on a few critical areas. Government aid was important in the early stages of the industry, both as a source of money and as a secure market. Today, however, private companies are the source of most innovations and products, with the exception of a few very high-risk/high-cost areas such as laser fusion and optical computers.

The Industry Today and Tomorrow

Private Companies - Approximately 200 companies belong to the Optoelectronic Industry and Technology Development Association (OITDA), the principal trade association in Japan. OITDA conducts long-range growth studies. It also publishes an annual survey of the industry based on the activities of its members, which are drawn from practically every manufacturing

field and most of the important service fields. While only estimates, these survey results have some weight because of the association's broad base.

According to the association's fiscal 1983 survey, light-emitting diodes held the top sales spot at some Y60 billion ($250 million); fiber-optic communications equipment rang up Y45 billion ($188 million) in revenues; optical fibers had Y25 billion ($104 million) in sales; laser video and audio disc equipment, laser printers, laser machine tools and light sensors took in approximately Y17 billion ($71 million) each; and grouped at the bottom were lasers of all types, solar cells and photoreceptor components, with sales of Y15 billion ($63 million) each.

The industry is dominated by Japan's electronics giants, including NEC, Fujitsu, Ltd., Hitachi, Ltd. and Sumitomo Electric Industries Ltd. Rapid technological advances, however, have enabled smaller companies to grab a share of the market, either as subcontractors, such as Furukawa Electric Co., Ltd., or as specialized suppliers like Japan Vacuum Technology Co., Ltd. and Taisei Corp. Competition is hottest in the fiber-optic industry, attracting potentially powerful companies such as Mitsubishi Rayon Co., Ltd. and Asahi Chemical Industry Co., Ltd. The manufacturing equipment market involves numerous companies pursuing specialized segments. Toshiba Corp. and Yaskawa and Co., Ltd, for example, have produced laser-equipped robots that possess adequate flexibility to be applied in a number of situations and are priced between Y30 million and Y60 million ($122,000 to $245,000), depending on options. Solar cell output is projected to quadruple by fiscal 1985, supplying as much as 13 percent of Japan's total energy consumption and offering the handful of companies dominating this market long-awaited profits.

As indicated in Table 1, total industry demand is forecast to remain very strong through the year 2000. It is interesting to note that the share of complete systems is expected to grow significantly, an indication of the long-term strategy of Japanese companies. In the short-term, however, there is evidence that Japanese firms are having trouble making the transition from manufacturing components to assembling pieces of equipment.

A more detailed medium-term demand outlook is given in Table 2. It also shows spectacular projected growth rates. Rapid growth resulting from the liberalization of Japan's domestic telecommunications market could lead to a boom of the magnitude projected. Even if OITDA's forecasts prove to be wildly optimistic, the industry should experience above-average growth for several decades.

From a global perspective, some observers consider Japan's optoelectronics industry to be on a par with this country's, but this is a hotly debated point. The Japanese do command about 40 percent of the $1 billion-plus global market for optoelectronic components. They have a smaller share of global optoelectronic systems sales, but are aggressively pursuing markets and customers.

Universities and Private Research Institutes - Japan's graduate and post-graduate institutions do not seem to play as large a role in the optoelectronics industry as they do in the United States or Europe. Research appears to be concentrated in particular areas and is not well-funded. Robotic

vision systems, precision measurement equipment and medical applications account for the lion's share of educational institution-sponsored programs. Some important advances have been made, including a practical three-dimensional vision system and creative uses of medical lasers, but the vitality exhibited by American universities is not present in Japan.

There are a number of reasons for this, but tight budgets and mountains of procedural regulations are the main culprits. There is no lack of student interest, but there is a shortage of competent professors. (Most top personnel are found in private corporations where the pay is significantly higher.) Nothing less than a complete overhaul of the education system is likely to alter this situation.

Government Programs - The close government-industry cooperation that has characterized a number of high technology fields in Japan is evident today in optoelectronics, although at a reduced level. To stimulate the industry in the 1970s, Tokyo was quite direct about protecting domestic producers, encouraging technology imports and fostering research. Once momentum was generated, the government withdrew to concentrate on specific high-risk projects. Old habits die hard, however, and Tokyo's continued protective impulses disquiet foreign companies and governments alike.

The Science and Technology Agency (STA), the Ministry of International Trade and Industry (MITI) and NTT have been the centers of government activities in optoelectronics. Under the aegis of the 1978 Extraordinary Measures Law for the Promotion of Specific Machinery and Electronics Industries (PL 84), MITI was directed to draw up general development outlines and encourage private firms to enter the field through research grants and joint projects. Several projects have been sponsored, including one to develop an optical instrumentation and control system and an integrated voice/video system now being rewired with fiber optics (the "Hi-Ovis" project in Higashiikoma).

MITI has also made four concessional loans to companies engaged in optical research. MITI has been instrumental in establishing (in 1979) and funding the Engineering Research Association of Optoelectronics Applied Systems, which operates the Optoelectronics Joint Research Laboratory (OJRL). In cooperation with fourteen major Japanese companies, OJRL leases space within Fujitsu's Kawasaki laboratory, where 50 researchers are working mainly on an optical logic element, the basis for an optical computer. The five-year project, which started in 1981, is budgeted at $80 million, and the research results will be shared among the contributors.

The Science and Technology Agency has devoted its efforts toward more esoteric applications, including laser interferometry, advanced optoelectronic materials and long wavelength lasers. These programs are not large and have no immediate commercial use. They could be important, however, if some practical problems can be overcome and some theoretical difficulties resolved.

NTT has probably played the most critical role in the development of the optoelectronics industry in Japan. In the 1970s, NTT poured hundreds of millions of dollars annually into fiber-optic projects in cooperation with private firms. Since NTT is barred from manufacturing any type of equipment, it developed close relations with a handful of supplier companies, including

NEC, Fujitsu, Oki Electric Industry Co., Ltd. and Hitachi. NTT's buy-Japan policy provided domestic producers with a secure market. In addition, NTT was willing to pay high prices for products developed to its specifications, perhaps contributing to the rapid development of a globally competitive industry. Although NTT's monopoly over the domestic telecommunications market is about to be broken, it will continue to play a major role in the industry's development since a significant portion of its $400 million research budget is devoted to fiber optics and many of its 3,500 researchers are working in this field.

In comparison with Japanese government efforts in other industries, support for optoelectronics is quite small. Projects aimed at biotechnology and electronics are both more numerous and better funded. As in other industries, it is difficult to gauge the effectiveness of the government's initiatives, but it appears that government programs provided an important boost to the industry in its infancy. At the same time, though, Tokyo seems to have reduced its presence in the industry as it has matured. Despite this pullback, the U.S. government is still uneasy about Tokyo's influence over the optoelectronics marketplace.

U.S.-Japan Competition in Optoelectronics

There are no specific points of friction between the U.S. and Japanese governments over optoelectronics, but the problems American makers of telecommunications equipment are said to encounter also face manufacturers of optoelectronics products. Access to Japan's telecommunications equipment market has long been criticized as nonexistent and NTT's procurement policies have come under special attack (see JEI Report No. 5B, February 3, 1984). The liberalization of Japan's communications market may defuse these issues -- unless Americans feel they are not getting a fair deal (see JEI Report No. 48B, December 21, 1984).

Japanese fiber-optic makers have also had their share of problems getting into the U.S. market. Fujitsu's low bid for a Boston-Washington optical cable planned by ATT was rejected in part because of rumblings from Washington about national security. To get around concerns about reliance on foreign manufacturers for defense-sensitive products, Fujitsu, NEC, Sumitomo Electric and Fujikura, Ltd. are building or plan to construct manufacturing facilities in the United States.

While this may eliminate the national security problem, Japanese companies face a strong legal challenge from Corning Glass Works over patents basic to the industry. Corning's suit contends that Sumitomo Electric's fibers infringe on several of its patents. The case is before the International Trade Commission (ITC) and could possibly lead to a ban on imports from almost every Japanese company. It is not at all certain which way the ITC will vote on this case, and Corning does not seem interested in an out-of-court settlement.

Technology transfers between private companies are numerous. Drexler Technology Corp. of Mountain View, California, has licensed seven Japanese companies to use its laser card technology. So many firms have agreed to use the Drexler information storage system that the Japan Business Machine Makers Association is moving toward adopting it as the Japanese standard. Technology

is flowing in both directions: Hewlett-Packard Co. will import Canon Inc.'s personal-size laser printer cartridges, while Shibuya Kogyo Co., Ltd. has obtained a license from Questek Inc. of New Bedford, Massachusetts to produce and distribute the American firm's excimer laser in Japan.

Conclusion

It is clear that close Japanese government-industry cooperation has yielded a world-class optoelectronics industry in less than ten years -- an achievement that makes its competitors uneasy. If Japan fulfills the letter and spirit of its planned telecommunications reforms, however, this unease should quickly evaporate. Competition between American and Japanese companies will be fierce, but there are also numerous opportunities for cooperation. Industry leaders and the governments of both countries are beginning to see the possibilities.

For further information, contact Jon Choy.

The views expressed in this report are those of the author and do not necessarily represent those of the Japan Economic Institute.

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Table 1: Annual Sales of Japan's Optoelectronics Industry

(in billions of yen and percentage of total sales)

	Actual		Estimated	Projected		
	FY 1981	FY 1982	FY 1983	FY 1985	FY 1990	FY 2000
Components	Y89.3 (55.9%)	Y165.3 (59.3%)	Y236.1 (54.8%)	Y194.0 (22.0%)	Y411.0 (19.0%)	Y2,639.2 (22.0%)
Equipment	42.7 (26.7)	83.5 (30.0)	142.0 (33.0)	563.4 (62.0)	1,362.9 (64.0)	5,037.8 (42.0)
Systems	27.8 (17.4)	29.7 (10.7)	52.6 (12.2)	146.0 (16.0)	350.0 (17.0)	4,294.0 (36.0)
Total	159.8 (100.0)	278.5 (100.0)	430.7 (100.0)	903.4 (100.0)	2,123.9 (100.0)	11,971.0 (100.0)

Source: Optoelectronics Industry and Development Association, Annual Survey, FY 1983

Table 2: Domestic Demand Outlook for the Optoelectronics Industry

	1983	1988	Annual Growth
Semiconductor Lasers (pieces)			
1.55 microns	0	500	--
1.30 microns	3,000	200,000	132%
0.85 microns	7,000	180,000	91
0.78 microns	500,00	7,000,000	70
Gas Lasers (units)			
Helium-neon	150,000	250,000	11
Argon	600	3,000	38
Carbon dioxide (CO_2)	300	1,500	38
Excimer	40	320	52
Solid Lasers (units)			
Ruby	15	15	0
Quartz	30	30	0
Yttrium-Aluminum-Garnet(YAG)	570	2,100	30
Dye Lasers (units)	50	250	38
Light-Emitting Diodes (pieces)			
Display	1,820,000,000	6,880,000,000	30
Alpha-numeric	98,000,000	292,000,000	24
1.55 microns	0	0	--
1.30 microns	2,000	670,000	220
0.85 microns	90,000	1,400,000	73
Discrete Photoreceptors (pieces)			
Photodiodes	30,000,000	75,000,000	20
Phototransistors	80,000,000	360,000,000	35
PIN (Si)	680,000	1,300,000	14
Avalanche diodes	13,000	160,000	65
Long wavelength	15,000	1,012,000	132
Array Photoreceptors (pieces)			
One-dimensional	350,000	1,000,000	23
Two-dimensional	500	350,000	270
Complex Opto-Elements (pieces)			
Photocouplers	120,000,000	320,000,000	22
Photointerrupters	60,000,000	180,000,000	25
Solar Cells (Kilowatts)			
Personal use	2,300	9,400	33
Power generation	900	22,000	90
Optical Fibers (kilometers)			
Multimode, silicon	4,000	20,000	38
Multimode, germanium	24,000	770,000	100
Singlemode, quartz	44,000	250,000	42
Multimode, composite	5,000	100,000	82
Polarized	80	610	50
Bundled fibers	150	180	4
Optoelectric Components (pieces)			
Demultiplexers	2,000	20,000	58
Multiplexers	1,000	1,200,000	313
Filters	4,500	200,000	114
Isolators	250	20,000	140
Light switches	450	100,000	195
Light connectors	170,000	6,300,000	106
Medical Lasers (units)			
Eye-use	170	280	10
External-use	130	260	15
Internal-use	30	250	53

	1983	1988	Annual Growth
Light Transmitters (units)			
Digital, simple	50,000	1,200,000	89%
Digital, general	1,000	14,000	70
Analog, simple	1,500	180,000	161
Analog, general	100	260	21
Optical modems	1,500	9,000	43
Traveling-wave tubes	100	10,000	151
Light Transmitter Testers (units)			
Standard light source			
1.30 microns	500	2,400	37
0.85 microns	100	460	36
0.78 microns	100	1,000	58
Power meters	5,000	12,000	19
Baseband testers	100	400	32
Phase detectors	0	170	--
Attenuation meters	200	1,500	50
OTDR (units)	400	1,000	20
Spectrometers (units)			
Interferometers	20	150	50
Spectral analysers	70	400	42
Construction Machinery (units)	700	3,000	34
Optical Sensors (units)			
Ohmmeters	40	500	66
Voltmeters	40	150	30
Temperature	50	50,000	298
Flow	60	5,000	142
Vibration	80	800	58
Pressure	0	800	--
Distance	320	1,100	28
Depth	180	1,000	41
Optical Disc Players (units)			
Consumer video discs	70,000	500,000	48
Write-only video discs	150	1,500	58
Read-write video discs	0	500	--
Audio discs	100,000	1,700,000	76
Optical Printers (units)			
Semiconductor laser	5,000	160,000	100
Solid laser	1,200	3,000	20
LED	200	30,000	172
LCD	0	15,000	--
Laser Scanners (units)	2,000	15,000	50
Manufacturing Lasers (units)			
Cutters, YAG	15	80	40
Cutters, CO_2	65	500	50
Welders, YAG	100	540	40
Welders, CO_2	25	280	62
Laser markers, YAG	50	450	55
Laser markers, CO_2	30	450	72
Inscribers, YAG	5	10	15
Inscribers, CO_2	25	90	29
IC trimmers, YAG	190	580	25
IC mask exposers, YAG	35	120	28
IC mask exposers, CO_2	0	10	--

Source: Optoelectronics Industry and Development Association, Medium-Term Outlook, FY 1984